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CAVING PROCEDURE AT THE CRESTMORE LIMESTONE MINE
of the
RIVERSIDE CEMENT COMPANY, RIVERSIDE COUNTY, CALIF.

by
RANDALL H. WIGHTMAN

A
THESIS
submitted to the faculty of the
SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI
in partial fulfillment of the work required for the
Degree of
ENGINEER OF MINES

Approved by

J. D. Forester

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INTRODUCTION

The following paper describes current mining practices of the Riverside Cement Company at its Crestmore Mine, Riverside, California.

For a number of years the Riverside Cement Company obtained its raw materials by surface quarry operations, but after these deposits were exhausted for equipment available at that time, the Company started underground mining. Mine workings were begun in 1927 to 1930 for the recovery of limestone by block-caving methods.

GEOLOGY

The bed of limestone that is being worked is a metamorphosed and recrystallized limestone, which is generally white in color and from medium to coarsely crystalline. This bed is fissured by water courses that vary from minute cracks to large areas. The bed has also been cracked by intrusions along the footwall and hanging wall. These walls are coarse-grained, gray, quartz granodiorite.

The strike of the deposit is north and south and it dips to the east at an angle of approximately 50° . The bed is approximately 1700 feet long, 270 feet thick at right angles to the dip at the middle of the deposit and tapers to a thickness of approximately 100 feet at each end.

MINING METHODS

The mine layout consists of four main levels with elevations as follows:

- 892 Collar of shaft.
- 800 Manway level used for ventilation, prospect purposes and as an entrance into the stopes.
- 700 Mining level where all material is extracted and on which are located the tapping grizzlies. This is the elevation from which all main cutoff stopes and undercutting work is started.
- 660 Haulage level where the limestone is drawn from transfer raises into the cars and is transported to the tipple by electric locomotives.
- 633 Level where all water is collected and which keeps the general water table below the working levels.

A detailed description of the mine was given in U. S. Bureau of Mines Information Circular No. 6795, in June 1934.

CURRENT BLOCK DEVELOPMENT

The first blocks to be caved were developed very much after the procedure followed in the copper mines of Arizona. This paper covers the ninth block to be caved. With a hard, tough rock like our limestone, it was found that some alterations in the development and control of draw in caving were necessary to secure better crushing effect and provide more safety for such secondary blasting as is required.

SEQUENCE OF BLOCK DEVELOPMENT

The fringes of the 800-ft. manway level are driven to confirm the diamond-drill information and serve to determine the final location and development required for the block (Fig. 1).

The haulage laterals on the 660-ft. level, at 70-ft. centers, are driven off the main haulage drift. The ground is hard and no timbering is required (Fig. 3).

Raises are then started from the haulage level at 35-ft. centers and draw sets are installed. From the draw positions on the haulage level, three raises are driven to connect with the mining drifts above at the proper positions - a two-branch raise from one side and single raise from the opposite side of the draw set. At alternate draw positions, the two-branch raises are put up on opposite sides of the haulage drift (Figs. 2 and 3).

Mining drifts on the 700-ft. level are then driven at 35-ft. centers, a minimum of tramming being required because the raises at about 25-ft. centers on the 700 level are in position to be used for the disposal of the development muck by gravity (Fig. 2).

While the primary development is nearing completion, raises to serve for stope ventilation and for handling supplies into the stope from the 800-ft. manway level or from the surface are driven from the 700-ft mining level to the surface, or to the 800-ft. level if the stope is in the hanging wall.

STOPPING

In the ground of the Crestmore mine, it is necessary that the block be completely cut off on all four sides. In the block illustrated, the north side is against the caved area, hence the other three sides are cut off from the

surrounding rock by shrinkage cutoff stopes.

At least two cribbed manways, made of 4 by 6-in. framed timber, 4 by 4 ft. inside, are carried up with the stope advance in all stopes. These are recessed in one side of the stope, in order to prevent crawling of the cribbing during shrinking of the stope.

All stopes are worked as shrinkage stopes and it is the general practice when driving to drill and blast about one half of a stope at a time, so that one manway is available for entrance to the stope. Fuse and caps are generally used in blasting but when the ground requires it electric blasting is used, for reasons of safety. It is seldom necessary to use stulls in stoping work.

In the block illustrated, the north side was exposed to the caved area and at the ends of the cutoff stopes adjoining this area tests were made at frequent intervals to make certain that only a very thin pillar would be left between the ends of the stopes and the caved area. This procedure is followed also at the corners of adjoining cutoff stopes.

When completed, all stopes are left full of broken rock until caving of the block is undertaken.

1770 EAST CUTOFF STOPE

The first development is the driving of openings 4 ft. wide and 5 ft. high from each draw poing in the tapping drift, about 14 ft. to the west (Figs. 4 and 7). Connections, parallel with the tapping drift, which form the bottom of the stope, were made as flat as possible and were driven

so as to leave approximately 6 ft. of rock between the stope and the adjoining tapping drift. Most of this development is done with Leyner drifters.

Because of the dip of the bed, this stope was driven 12 ft. wide and at such an angle to the 800-ft. level that it leans over 25 ft. at the 800-ft. elevation. It was driven vertical and about 8 ft. wide from the 800-ft. elevation to the surface. Experience has taught us that this is the limit of leaning over within which it is possible to shrink the stope and cave this type of ground successfully. The block is so laid out that the small amount of rock remaining between the stope and the footwall is recovered eventually by blasting in- to the caved area.

800 NORTH CUTOFF STOPE

From the south draw positions in the five tapping drifts, as illustrated in Figs. 5 and 7, connections were driven as flat as possible between the drifts; then connections were driven over each of the drifts, so as to leave a 13 ft. pillar over the top of the drifts for protection. This stope was then driven to the surface or to the contact. At the west end, it was driven to conform with the 1770E cutoff stope.

1970 EAST CUTOFF STOPE

The irregular contour of the 1970E stope (Figs. 6 and 7) is to conform with the limits of the limestone in this area. The stope connections were made similar to those as described under the 1770E cutoff stope; and this stope was driven vertical to the hanging wall contact.

UNDERCUTTING AND CAVING

It has been determined by experience that the success of the caving of a block requires extreme diligence in the undercutting procedure.

UNDERCUT DEVELOPMENT

Openings 4 ft. wide and 5 ft. high are driven from the draw positions on the mining level at right angles to the tapping drifts about 14 ft. on either side of the drift. Connections that form the bottoms of these stopes are then made parallel with the drifts and as flat as possible, as in the connections in the main cutoff stopes. These connections are driven so that a pillar of rock about 5 ft. thick will remain between the side of the drift and the adjoining undercut stope on either side of the drift, and a pillar about 8 ft. thick will remain between the adjoining undercut stopes, approximately half way between the tapping drifts (Figs. 7 and 8).

Because production requirements may vary considerably and on very short notice, development of blocks to this stage is carried well in advance of requirements, as no damage or ill effect is sustained in this ground by allowing the development to stand for a long period of time. No air slacking and/or side and bottom pressure is experienced. After the development has been completed to this stage, the block can be undercut and caved in a comparatively short time, and in accordance with the production requirements.

UNDERCUT STOPING

After it has been decided to bring in a block, the

undercut stoping is begun. Experience indicates that it is desirable to cave this ground by retreating from the footwall side to the hanging-wall side of the block.

Section BB of Fig. 8 illustrates irregularities in the undercut stopes at the turn of the tapping drifts, owing to the shape of the deposit at this location. Section AA represents the typical section through the block.

The first stopes driven were the Nos. 1-B, 2-A and 2-B, as shown in Figs. 7 and 8. After these stopes were driven to the desired heights, as illustrated, the next step is the removal of the pillar between the 1770E cutoff stope and the No. 1-B undercut stope, followed by the final round in the back of the 1-B stope.

It has been found necessary to thoroughly blast and completely remove pillars, in order to obtain successful caving of the block; and care is exercised to see that no pillars are left between the ends of stopes and adjoining caved area of previously caved blocks.

The blasting of pillars between stopes is undertaken in sections of approximately 30 ft. at a time, so that there will be no possibility of leaving even a small part of the pillar to cause difficulty in the future caving of the block. This blasting usually is accomplished with fuse and caps. If excessive weight develops on any of the pillars, larger sections are removed, and for this electric detonation is employed.

All undercut stopes are driven as shrinkage stopes, only sufficient broken rock being drawn to provide working space.

When completed they are left full of broken rock. Two cribbed manways are carried in each set of stopes.

CAVING THE BLOCK

In the first blocks caved it was found that if the pillars under too large an area were blasted at once there was a tendency for the entire area undercut to drop, thus eliminating the benefit of the desired general fragmentation throughout and making necessary an additional undercutting operation.

The present procedure in starting to undercut a block is to complete at least the first three stopes, including the holes in the final round in the back of the stopes, as well as the holes for the removal of all pillars. Before a pillar is removed, the next two succeeding stopes should be completed, including the final round and holes for removal of their pillars. This sequence of operations is carried throughout the block. The usual procedure is to advance the stopes on either side of each tapping drift as a pair, cutting openings in the intervening pillar as a means of entry.

The pillar between the 1770E cutoff stope and the 1-B undercut stope, as well as the final round in the 1-B stope, are blasted. Openings are next driven through the pillar between the 1-B and 2-A stopes at intervals and sufficient rock is drawn to indicate that the first pillar has been completely broken out. Normally little sloughing can be expected at this stage.

Next, the pillar between the 1-B and 2-A stopes and the pillar between the 2-A and 2-B stopes, as well as the final

round in 2-A stope, are blasted. As this work is being done in sections of approximately 30 ft. at a time, confirmation of satisfactory removal of the pillar is attained. After this pillar has been completely removed, some spalling from the back may be expected.

There is now present an overhang of approximately 60 ft., including the 25 ft. of inclination adjoining the 1770E cutoff stope, with nothing supporting this area.

Extreme care must be exercised at this point, as this is the beginning of the caving, where success or failure starts.

Slabs of rock begin to spall from the bedding planes and soon fill the space left between the broken stope rock and the mass above. When this occurs, just enough broken rock should be drawn to keep the spalling action working on up toward the surface. It should not be pulled so fast as to permit this action to reach the surface before the pillars between 2-B and 3-A and 3-A and 3-B stopes are blasted. If drawn too fast, this area will tend to shear from the uncaved section more or less perpendicularly to the surface without securing the proper over-all fragmentation desired. In addition, this procedure tends to build up such pressure on the uncaved pillars and tapping drifts as to shatter the ground. This creates a hazardous working condition when blasting the pillars, and may cause expensive work in rehabilitating the tapping drifts.

If no broken rock is drawn from the area and the mass is allowed to settle on the broken stope rock until all of the pillars in the block are removed, excessive weight is placed

on the tapping drifts directly below the area. The mass may then become so compact that it will have to be more or less undercut again in order to start working.

Judgment as to the control of the draw under the caved area is based upon observation of the fragmentation of the unsupported mass, largely by sound, and by observing the weight being taken by the first uncaved pillar. If the draw should be too fast, this pillar will show signs of compression failure.

Successive pillars are removed and the draw principle described above is applied until all pillars under the block have been removed.

After all of the pillars under a block have been removed, the maximum of fragmentation that can be obtained has been accomplished. At this point is started what is called "rocking the block", for the purpose of securing a maximum of crushing action of the large fragments of rock throughout the mass.

ROCKING THE BLOCK

Up to this point about all of the broken rock that has been drawn has been the broken stope muck, which has been replaced by spalling from the bedding planes. The crushing action of the large fragments throughout the block is now obtained by control of the draw, so as to shift the strains and stresses throughout the mass by changing the locations carrying the weight.

From a study of the crystallization, nature of the rock, water courses, as well as the reactions of the block to date, it can be determined fairly well where the fragmentation and

crushing have not proceeded as desired. The draw is then concentrated at points where it will tend to create both compression and tensile strains in the areas desired. As fast as such areas are noted, the draw is changed to create a continual rocking of the entire broken mass, with the view of keeping the entire area down on the pillars and not allowing any area to hang up or to create large cavities.

The broken stope muck in the main cutoff stopes is drawn only sufficiently to provide additional room for the expansion of the block proper as crushing progresses and additional space is required for this expansion. If this rock is withdrawn too rapidly, there is a tendency toward dilution, which is undesirable in the early stages of caving operations.

Care must also be exercised in drawing chutes adjoining the previously caved area to prevent funneling of dilution into the clean block, and to prevent the creation of a condition that may cause a large section to slough over into the old caved area.

As the draw progresses, an effort is made to maintain as nearly as possible an even draw throughout the block; provided, however, the draw at any given point is under no circumstances permitted to create a large cavity under a hung-up area. The main objective is to control the draw so that the entire block will be kept down on the pillars, where it is both economical and safe to work.

It is believed that the present procedure in caving practice has been largely instrumental in enabling the mine to

complete nine successive years without a lost-time accident.

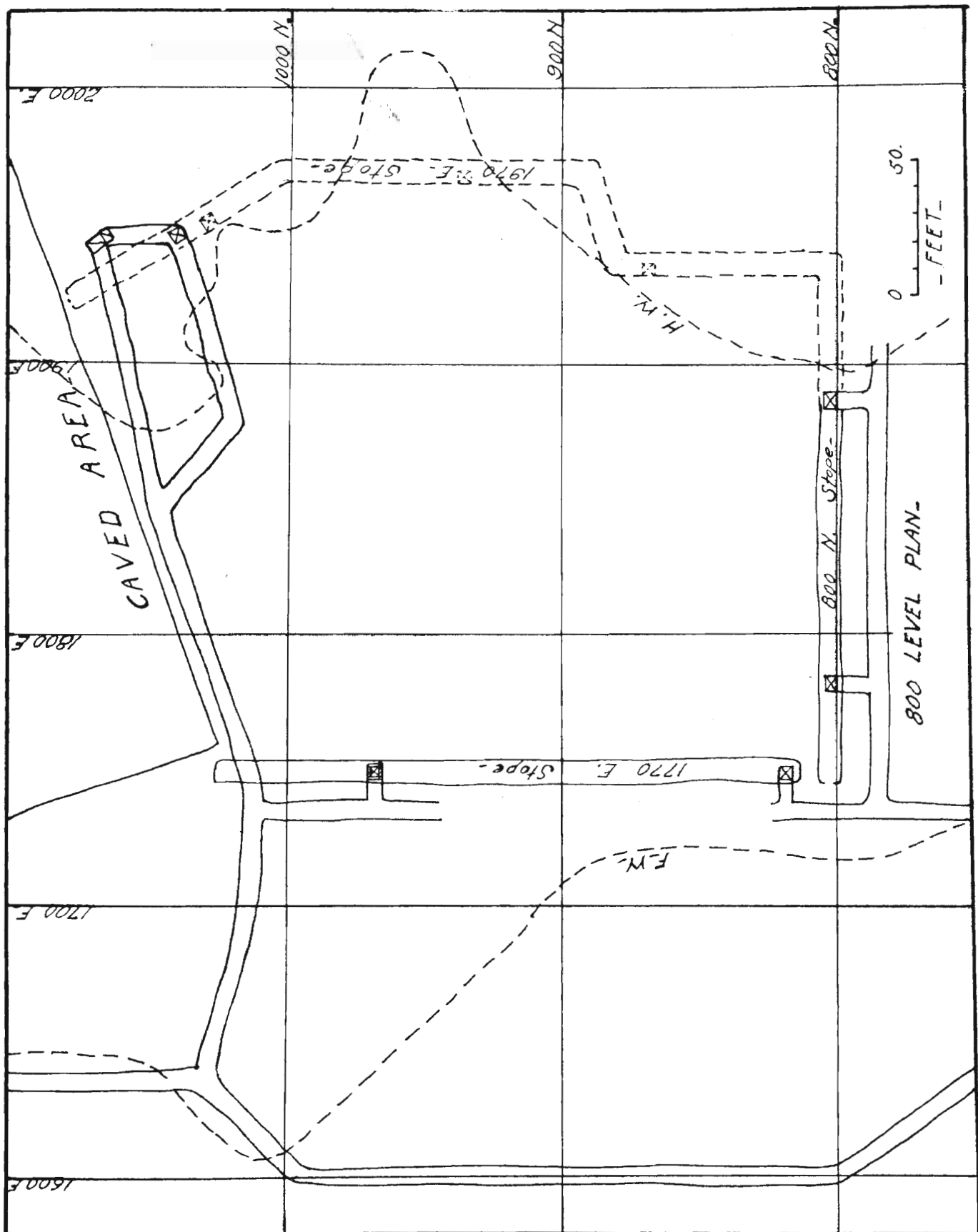
After a block is caved the overburden of granodiorite immediately breaks quite fine and the continuous rocking of the limestone tends to prevent the funneling of the overburden that is detrimental in the early stages of extraction. Although approximately a 20 per cent dilution is required in the manufacturing process, this material can be secured from the older blocks nearing completion and thereby provide a maximum of recovery of limestone.

After a block has been caved, it should be drawn to completion without interruption, for maximum efficiency and economy, and under no circumstances should it be permitted to remain idle for any length of time, because the mass becomes packed and considerable time and effort are required to start it working again.

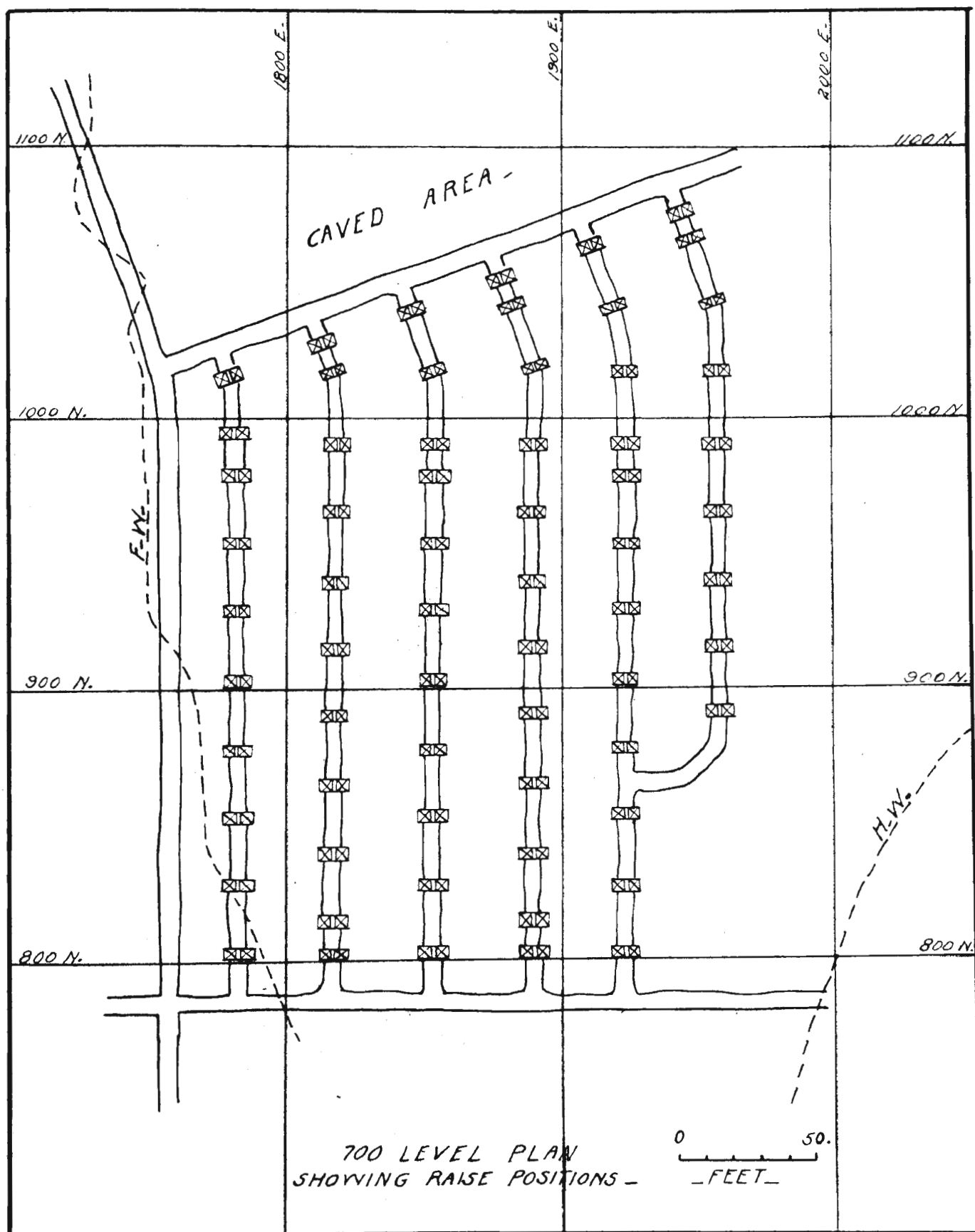
EXTENT OF OPERATIONS

Approximately 10 per cent of an entire block is broken in the main cutoff and undercut stoping operations at Crestmore. It is estimated that about 30 per cent of the limestone drawn from a block must be blasted by secondary blasting in order to make it pass the tapping grizzlies on the mining level.

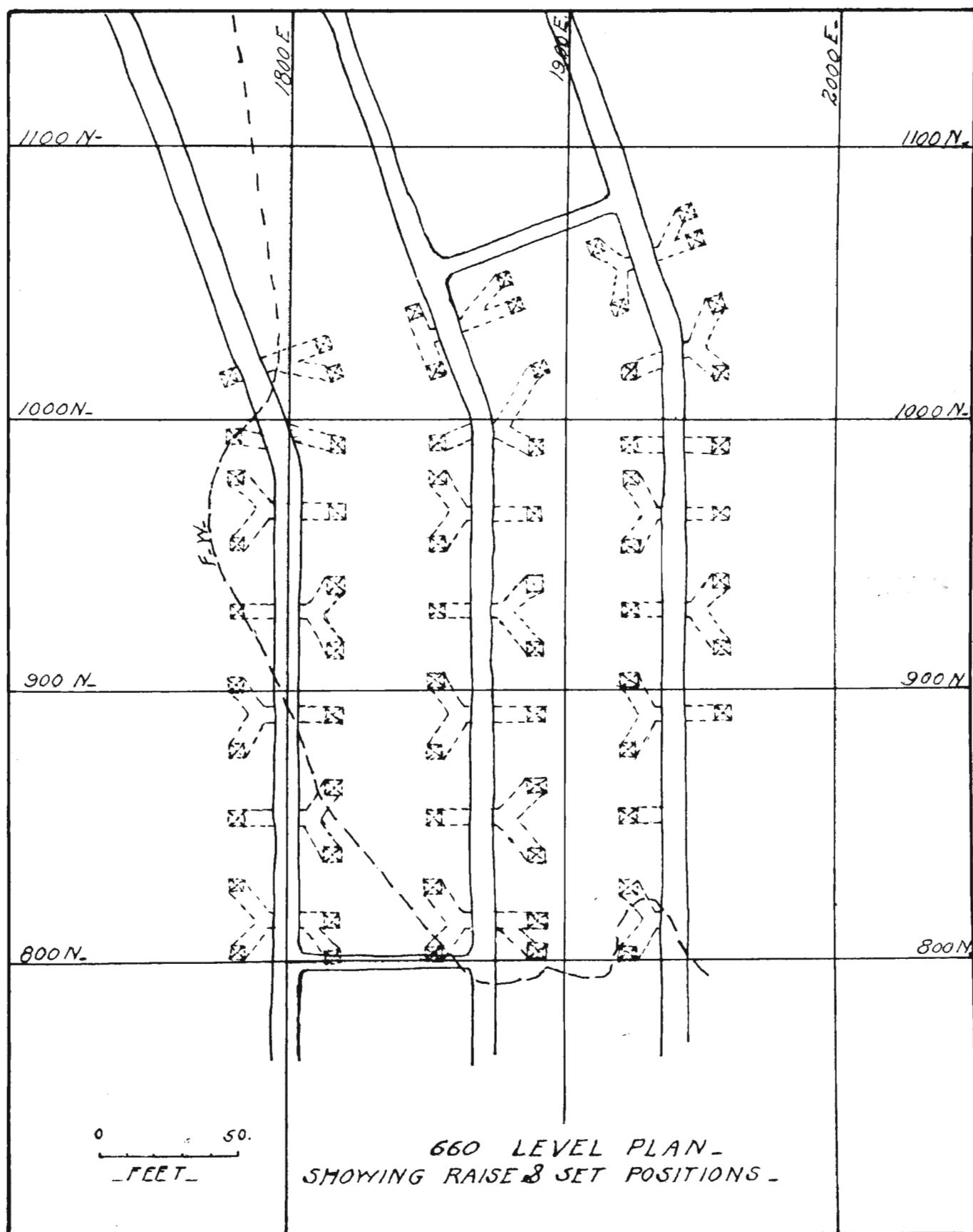
The block illustrated is approximately 210 by 260 ft., with a maximum height of limestone of 180 ft. Blocks 270 by 310 ft. have been caved successfully.



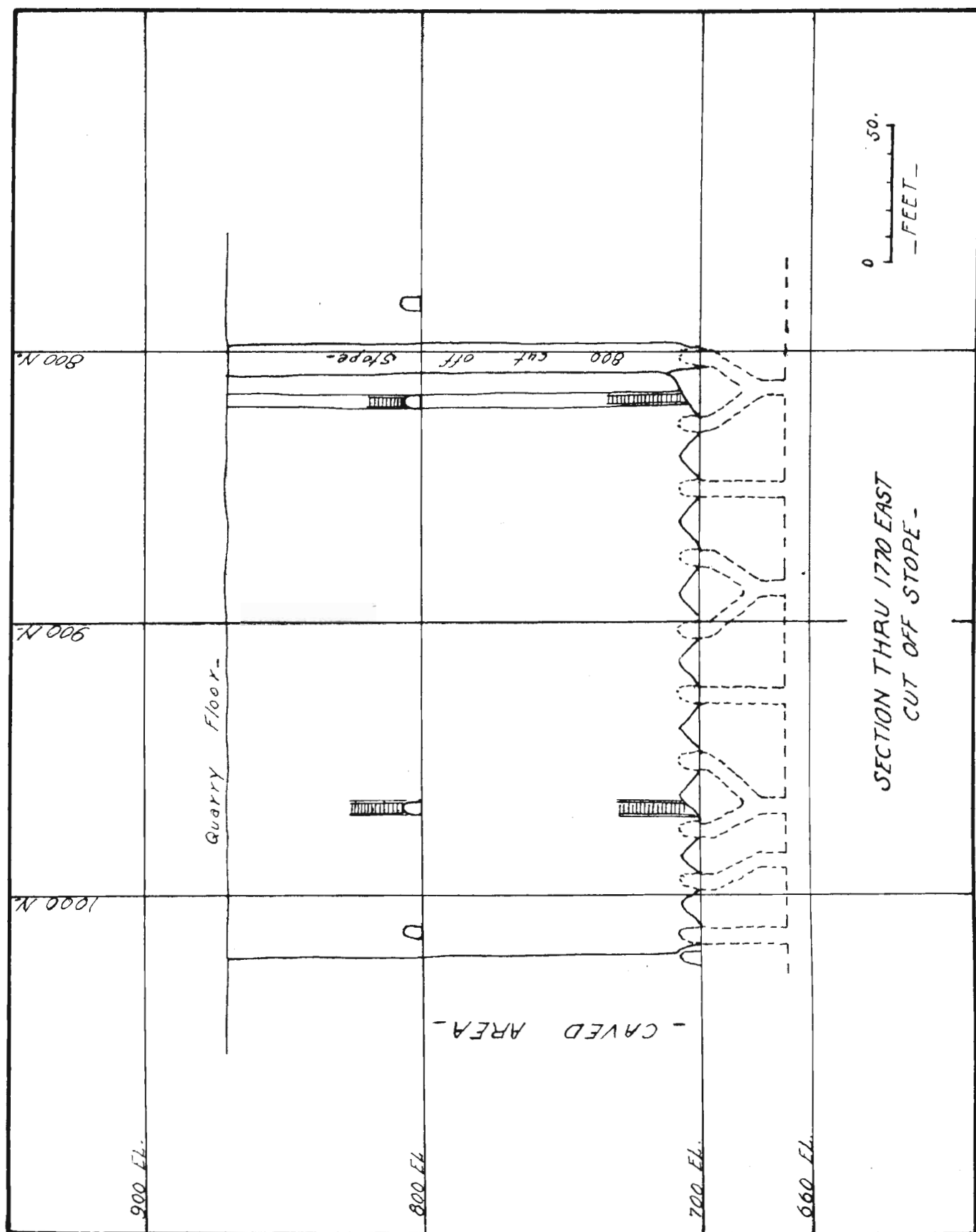
- FIGURE - I -



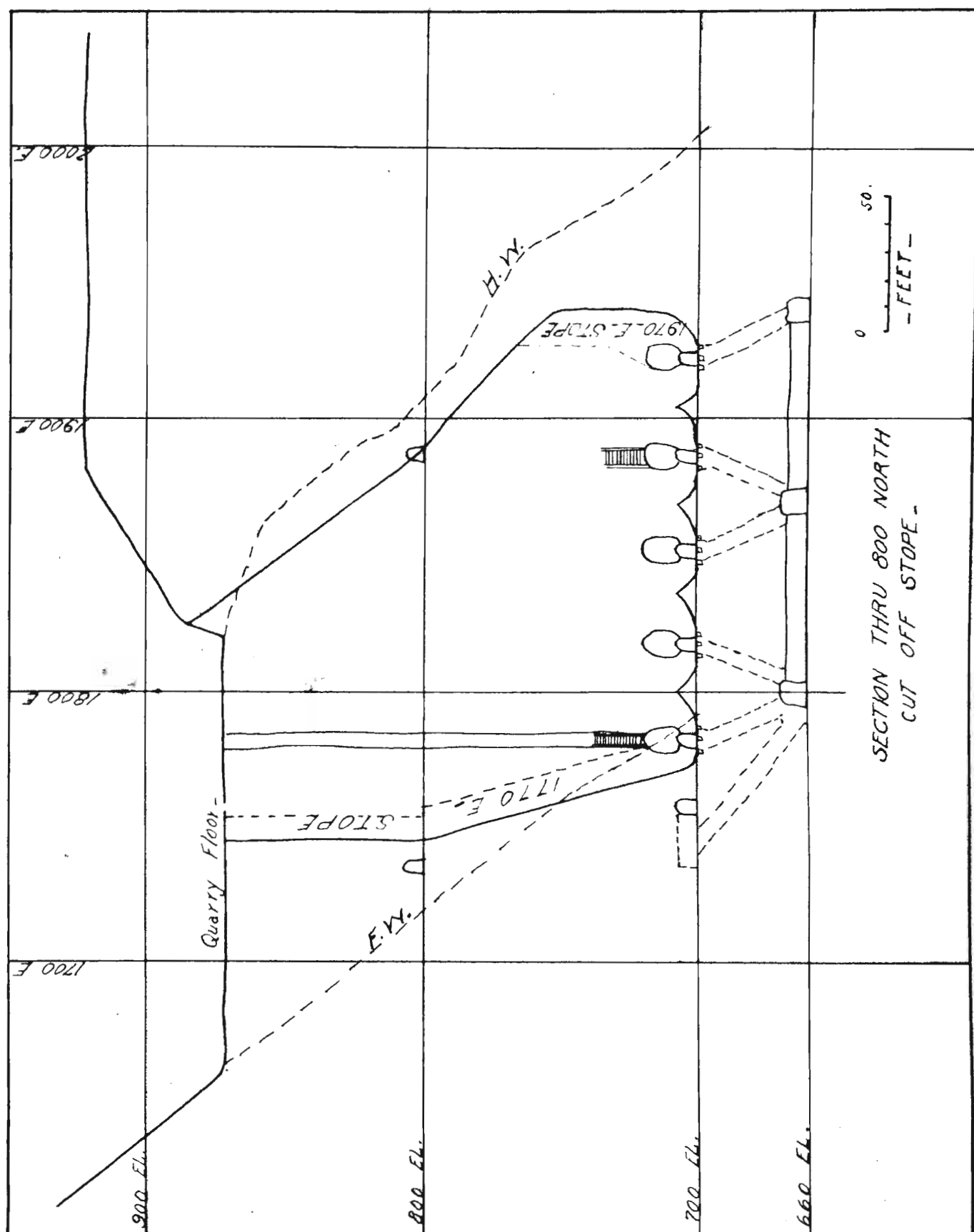
- FIGURE - 2 -



- FIGURE 3 -



- FIGURE 4 -



- FIGURE 5 -

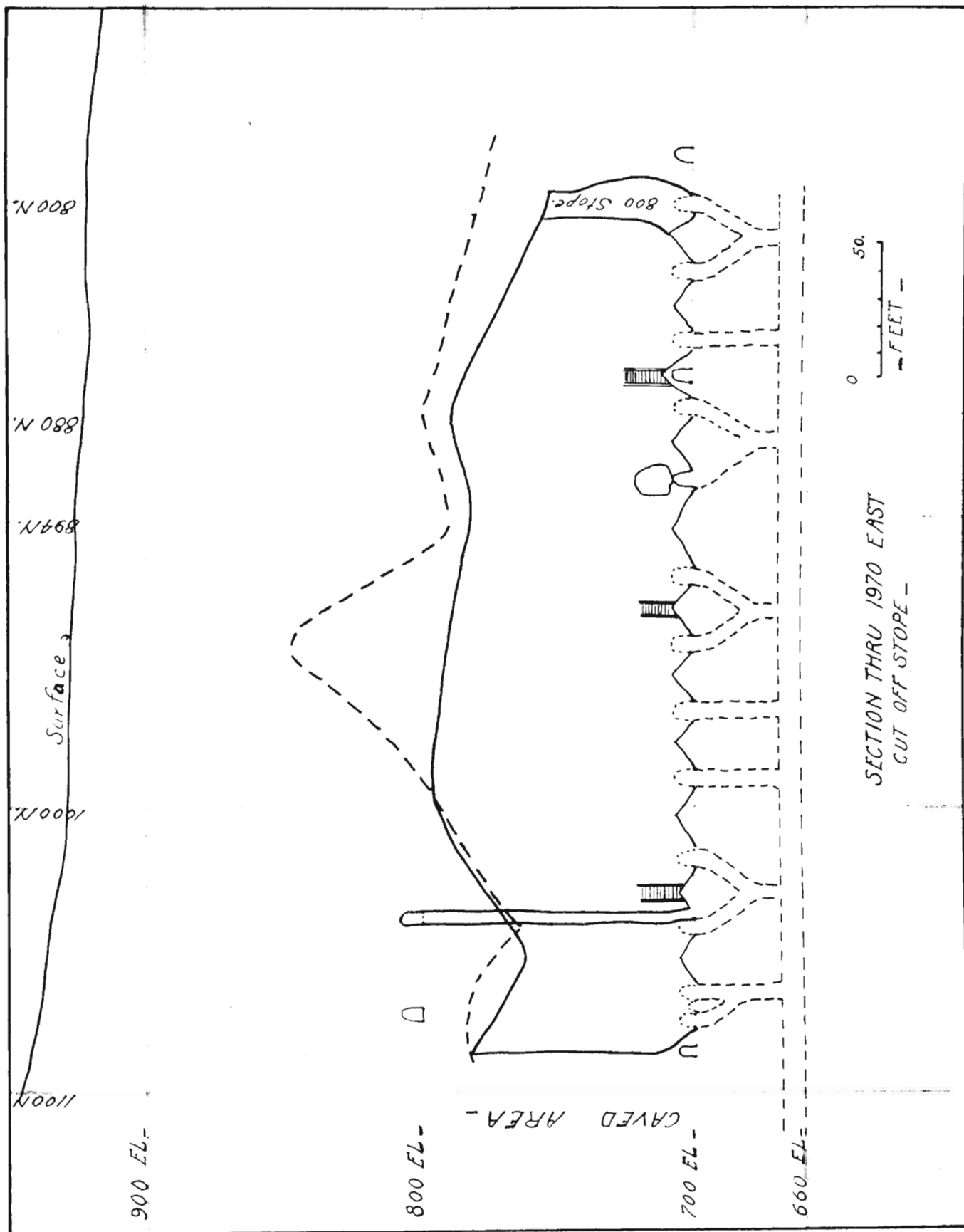
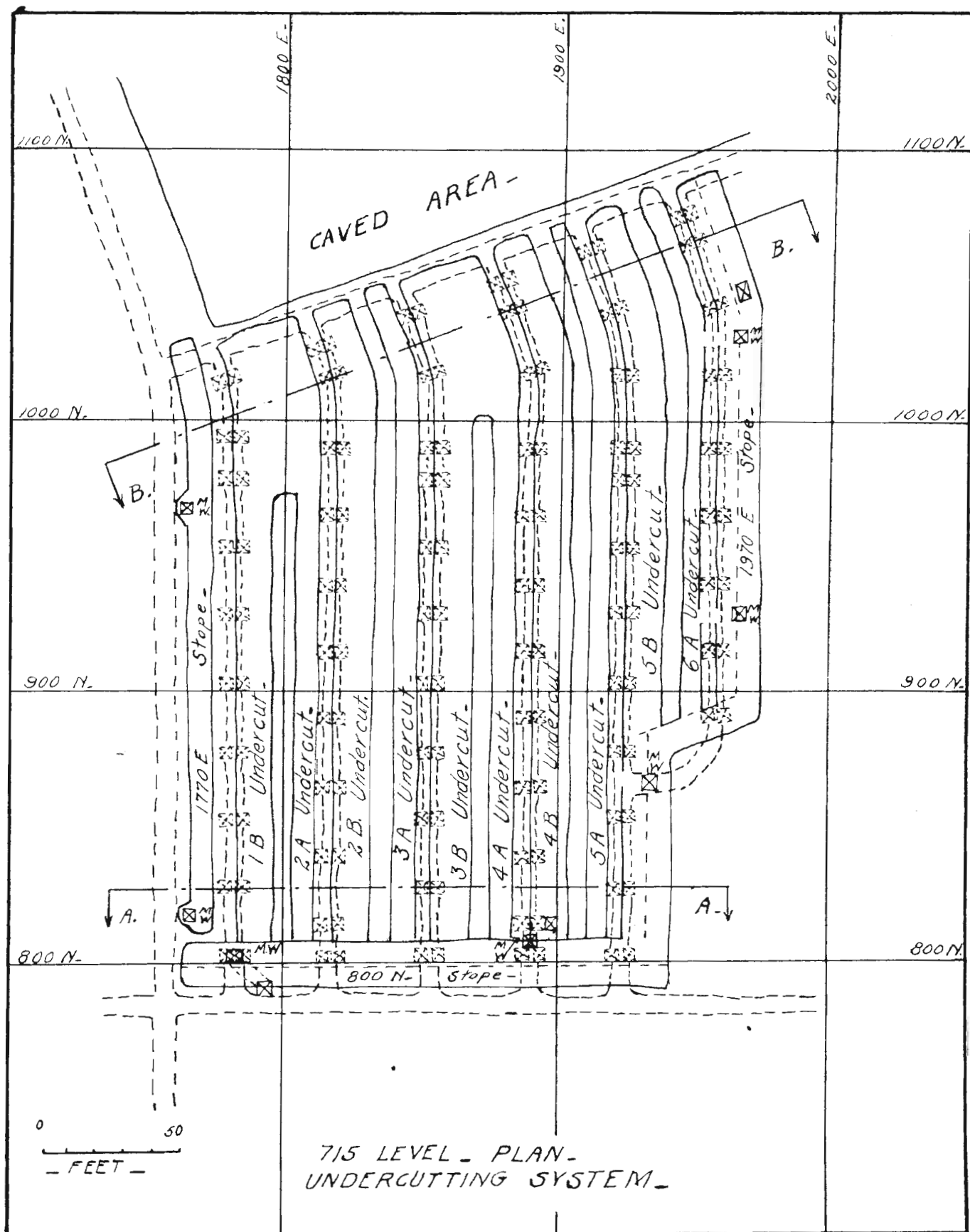
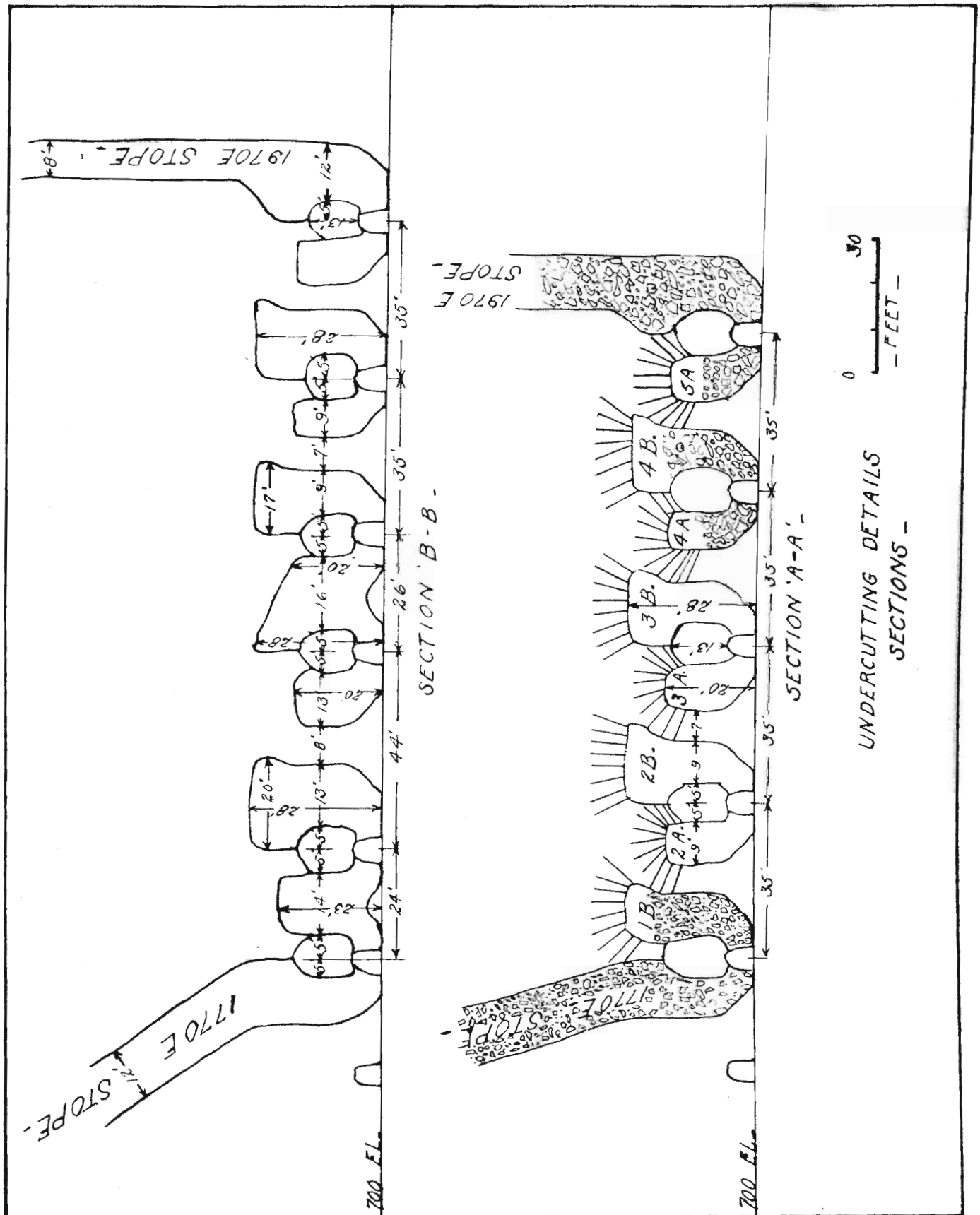


FIGURE 6 -



- FIGURE 7 -



- FIGURE 8 -